

# Analysis of Samples Returned from Space

Wally Calaway<sup>a</sup>, Igor Veryovkin<sup>a</sup>, Emil Tripa<sup>a</sup>, Mike Savina<sup>a</sup>, Don Burnett<sup>b</sup> and Mike Pellin<sup>a</sup>

<sup>a</sup> Materials Science Division, Argonne National Laboratory

<sup>b</sup> Division of Geological and Planetary Sciences, California Institute of Technology

## Motivation

- Understanding the formation of the solar system requires knowledge of the compositions of the sun and other non terrestrial bodies.
  - The Genesis and Stardust missions collected samples in space and returned them to Earth.
  - These samples are important for a better understanding of the creation of our solar system.
- Resonance Ionization Mass Spectrometry (RIMS) meets the stringent analytical requirements of samples returned from space.
  - The high sensitivity of RIMS permits ultra trace analyses.
  - RIMS consumes little material preserving these valuable sample.

## Accomplishments

- A new RIMS instrument has been designed and built.
  - High useful yield (atoms detected per atoms consumed) is ~20%.
  - Dual beam analysis for cleaning and high resolution depth profiles.
  - In situ optical microscope and secondary electron imaging.
- The first Genesis solar wind samples have been analyzed.
  - Depth profile of Mg in solar wind collector determined.
  - The fluence of  $^{24}\text{Mg}$  has been quantified as  $1 \times 10^{12}/\text{cm}^2$ .
  - Avoidance of particle contamination during analysis was proven.

## Impact

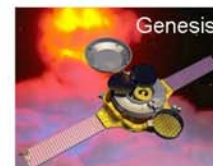
- The RIMS instrument performs quantitative mass analyses at concentrations, not achievable by other method, while consuming little sample, permitting new and exciting scientific investigations.
- Solar system formation models will be constrained and improved by RIMS quantification of many elements in the solar wind.
- RIMS measurements of the elemental and isotopic abundances of particles gathered from a comet is the earliest record of material from the solar nebula.

## Future Directions

- Genesis Solar Wind Samples:
  - Elemental fractionation between the solar wind and the sun due to ionization potential differences will be examined.
  - The abundances of many high z elements in the solar wind are unknown and will be determined by RIMS for the first time.
- Stardust Grains from Comets and Interstellar Particles:
  - Nanometer-scale isotopic analyses on particles are planned.
  - Multi-element RIMS analyses allow micrometer grains to be analyzed despite their limited number of atoms.

## Genesis Discovery Mission

The purpose of Genesis is to collect solar wind, the material ejected from the sun. Various high purity materials, which acted as collectors for solar wind, were returned to Earth in September 2004 and are now available for analysis. These samples contain a record of the elemental and isotopic abundances of the solar wind implanted in the near-surface region of the collectors.



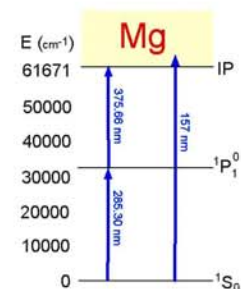
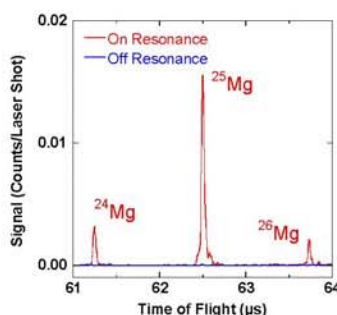
## Stardust Discovery Mission

Particles from comet Wild II and interstellar dust streaming through our solar system were collected in aerogel and returned to Earth by Stardust. The total mass of material collected is small making these samples extremely rare and valuable. Individual grains will be sent to select investigators worldwide.

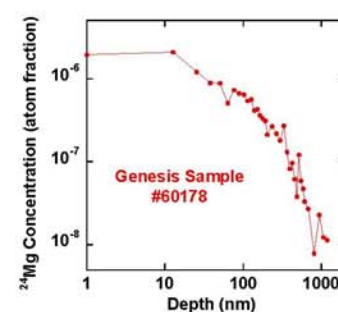
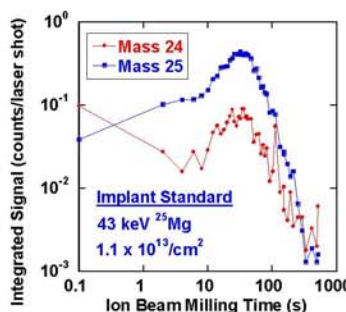


## Analysis of Genesis Samples

- Mg was chosen for first RIMS measurements on Genesis samples.
  - High abundance expected ( $2 \times 10^{12}/\text{cm}^2 \approx 4$  ppm).
  - RIMS/SIMS comparison possible.
- Resonance Ionization of Mg.
  - Two photon – two color scheme (below right) works well (below left).
  - Off resonance (285.30 nm  $\rightarrow$  285.26 nm) yields low background (below left).



- Enriched  $^{25}\text{Mg}$  implant (75%) was used to calibrate RIMS instrument.
  - Surface contamination ( $^{24}\text{Mg}$ ) observed on surface, but does not effect depth profile after 2 seconds of ion milling (~5 nm).
- Depth profile of Genesis sample shows little Mg surface contamination.
  - Measured  $^{24}\text{Mg}$  fluence =  $1 \times 10^{12}/\text{cm}^2$



I. V. Veryovkin, W. F. Calaway, C. E. Tripa, J. F. Moore, A. Wucher and M. J. Pellin, Nucl. Instr. Method B 241 (2005) 356-360.